



mmWave Technology Evolution From WiGig to 5G Small Cells

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Wireless Connectivity in Our Lives

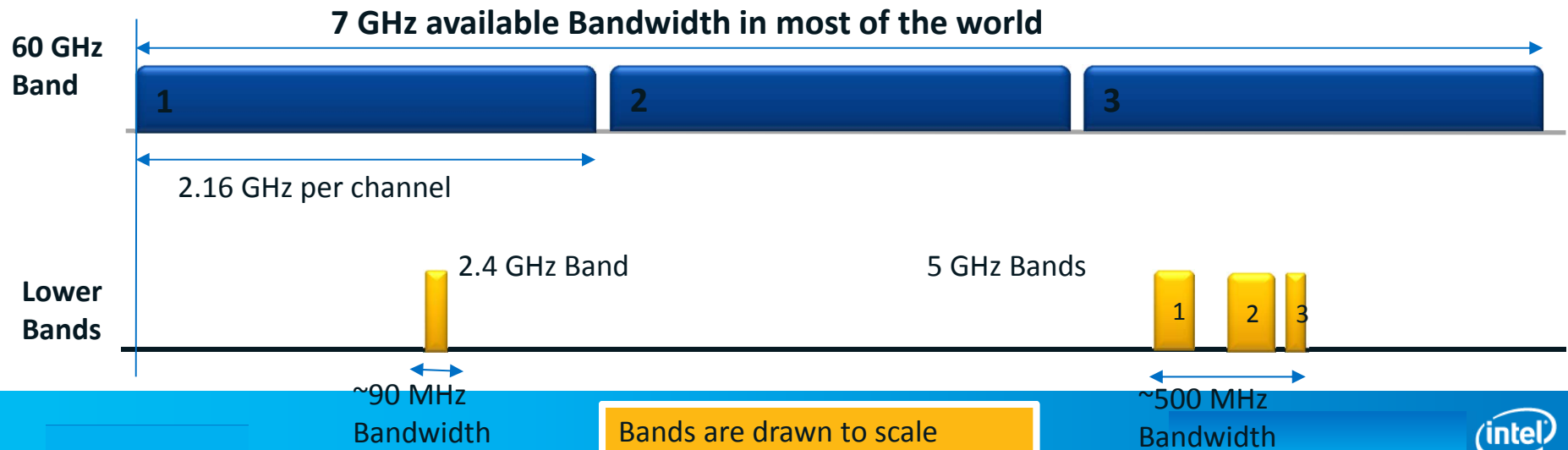
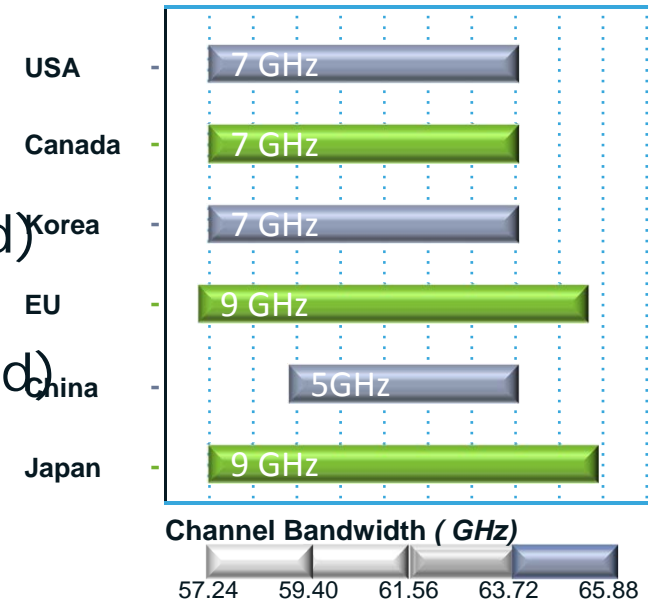


What Do We Have in Common?

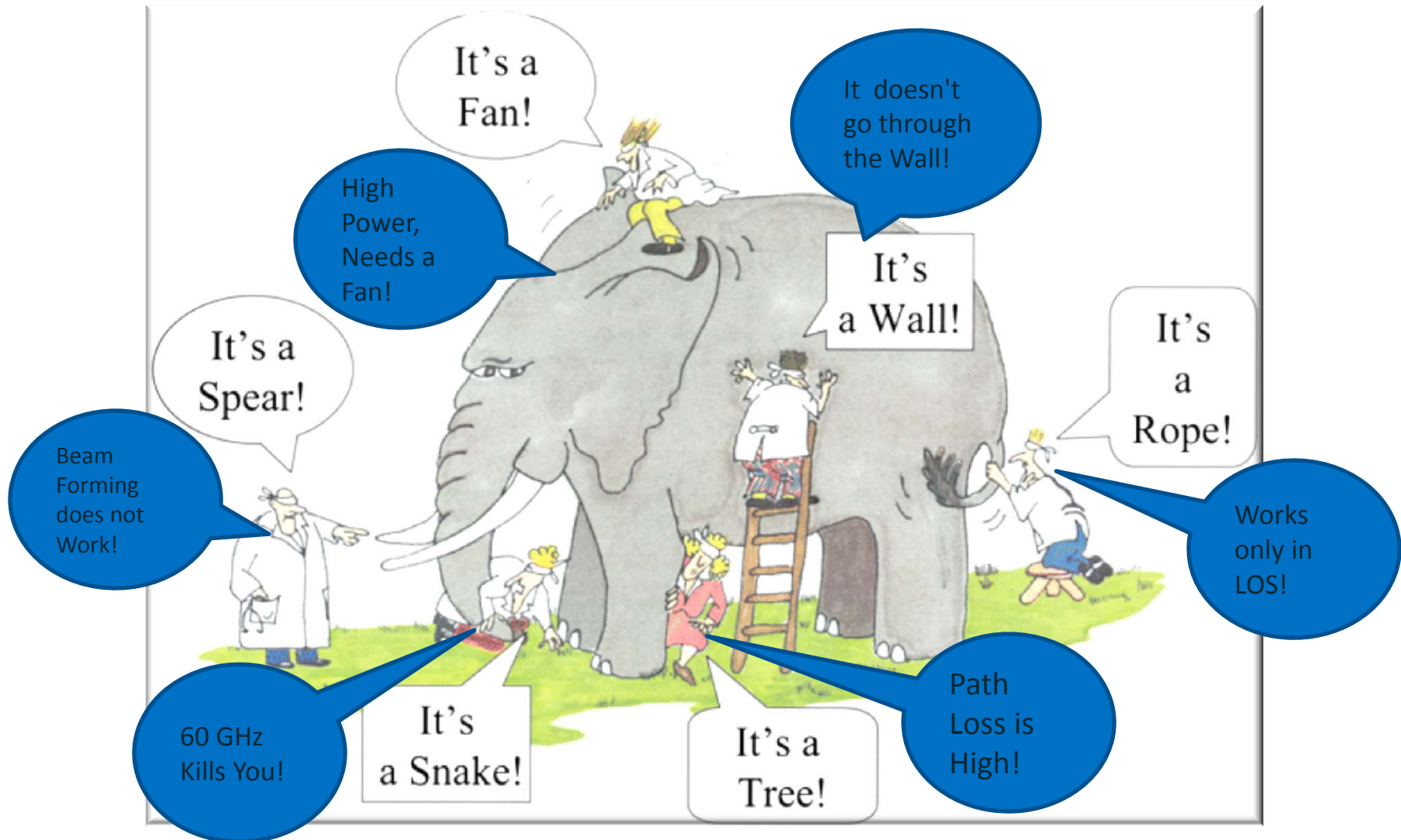
- 
- Smaller Form Factor!
 - Limited Connectors!
 - Limited Data Storage!
 - Larger Media Contents!
 - Fast Upload / Download!
 - Always Connected!

Available Unlicensed Frequency Bands

- The 60GHz band offers 5 – 9 GHz of unlicensed bandwidth across most Geographies.
 - 2.16GHz Bandwidth per channel
- Compared with:
 - ~90 MHz in ISM band (2.4GHz band)
 - 20MHz – 40MHz per channel
 - ~500 MHz in UNII band (5 GHz band)
 - 20MHz – 160MHz per channel



mmWave Challenges



mmWave Challenges



WiGig Usage Models

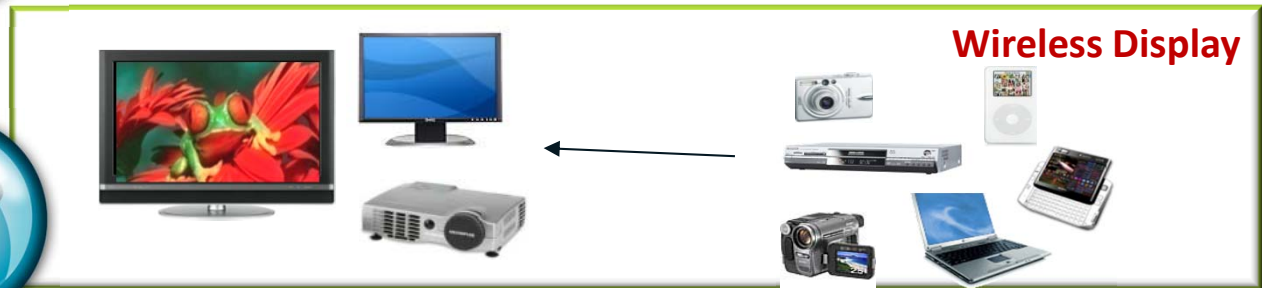
Instant Wireless Sync

- IP based P2P applications
- Wireless I/O
- Media HotSpot



Wireless Display

- HD streams over HDMI or DP
- CE & PC & HH usages
- Hulu, IPTV, YouTube



Wireless Docking

- Combination of Wireless display, sync and I/O

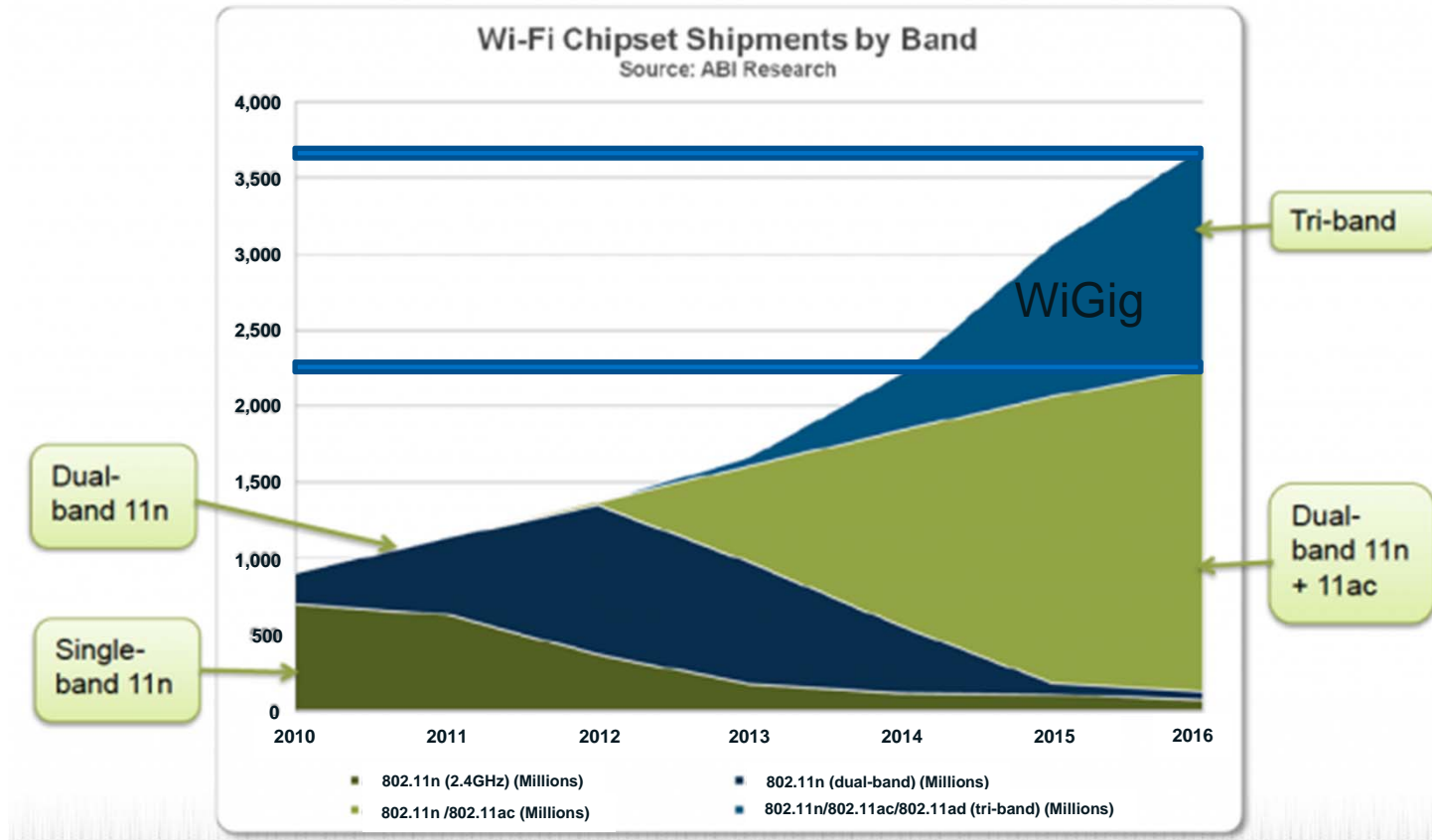


Access

- WiFi, IEEE TGad
- 3G/4G, Offload
- Small Cell Access & Backhaul



ABI Projection for WiGig Market



WiGig enabled chipsets will be over a BILLION units; almost 40% of all multiband chipset

WiGig Alliance Members

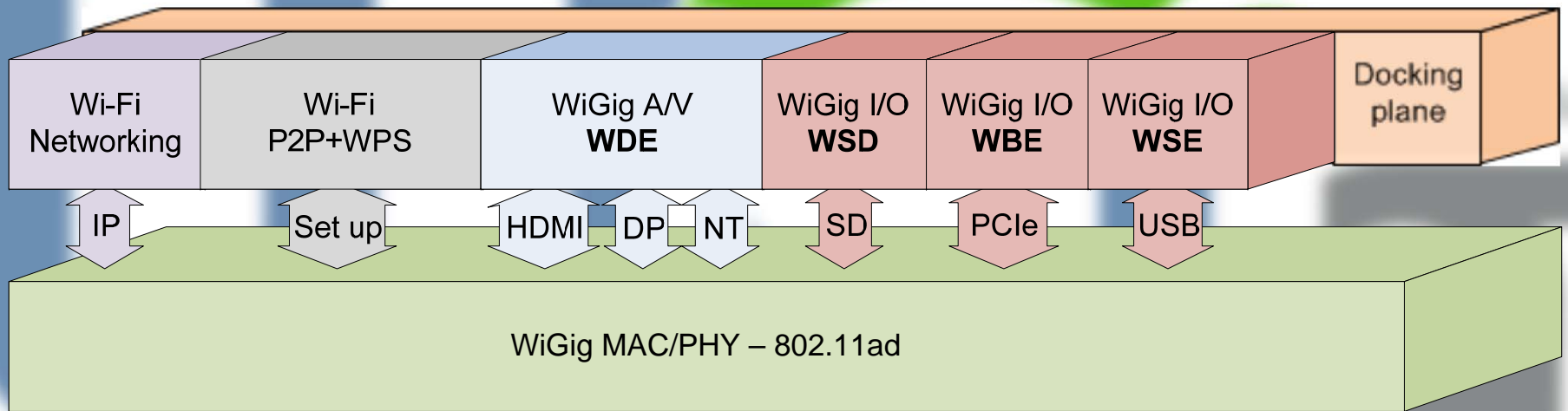
Board of Directors



Contributors



What is WiGig?



WiGig System Attributes

MAC

- Compatible with legacy 802.11
- Includes new PBSS mode (point to point)
- Includes new channel access (TDMA)

PHY

- Includes Single Carrier rates up to 4.62Gbps
- Includes OFDM rates up to 6.756Gbps

PAL

- WiGig Serial Extension(WSE) , USB payload over WiGig link
- WiGig Bus Extension(WBE), PCIe over WiGig link
- WiGig SDIO Extension(WSD), SDIO payload over WiGig link
- WiGig Display Extention(WDE), HDMI and DP over WiGig link

Industry Support

- Royalty free 60GHz standard with wide industry support
- IEEE 802.11ad publication by EOY 2012

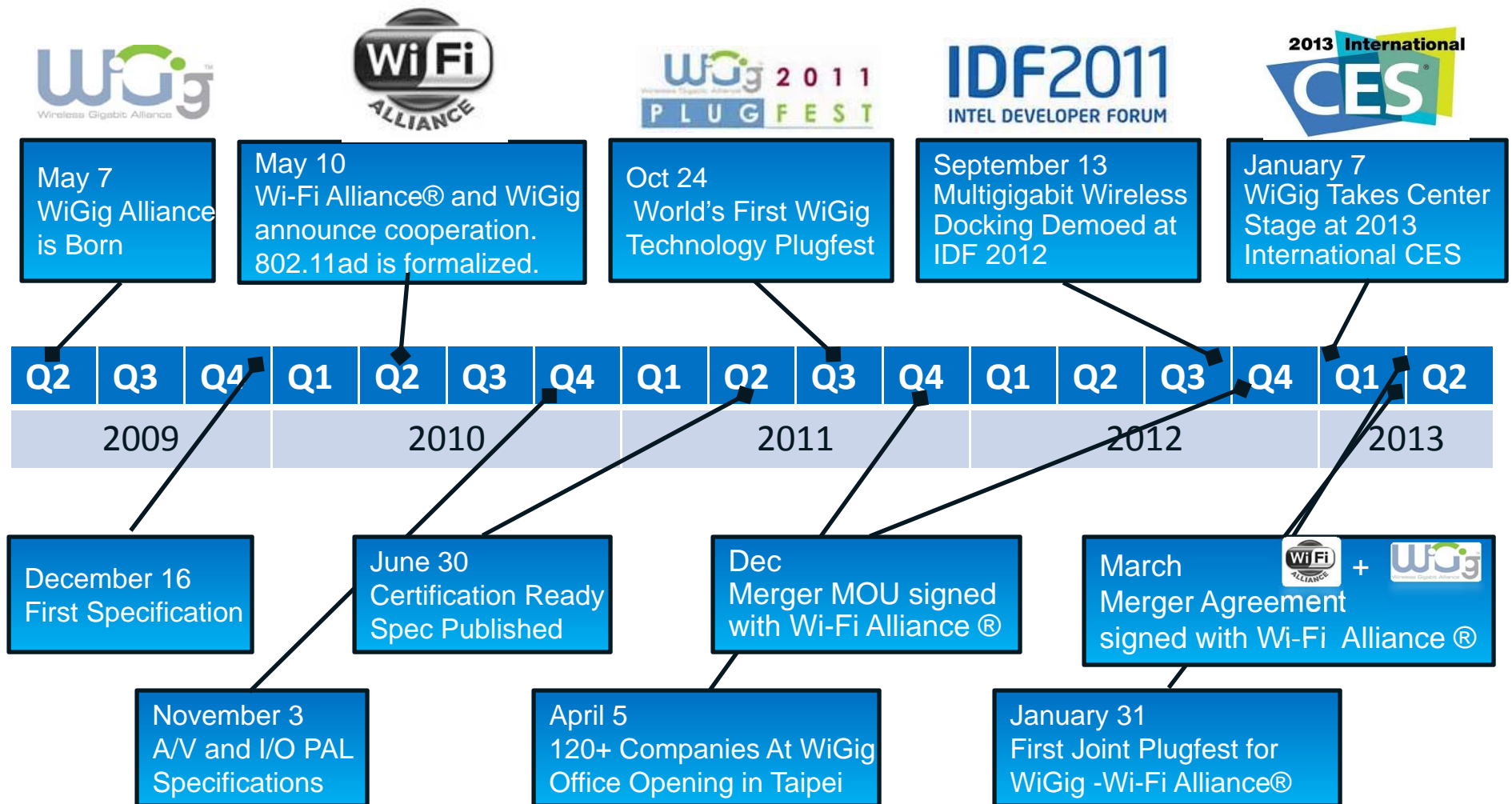
Interoperability

- Wi-Fi certified, Merged with WiFi Alliance

Regulatory

- Harmonized around the world
- ITU-R recommended

WiGig: Evolution of a mmWave Technology



WGA Merging with WFA

- Prevent ecosystem fragmentation, duplication and thus accelerate development & adoption
- Prevent confusion by delivering a high-impact integrated branding & communication
- Leverage existing brand recognition of WFA for MAC/PHY cert, USB for WSE cert and VESA for WDE cert
- Make efficient use of resources (people, travel, fees, certification, etc.)

WiGig Usage Models

Instant wireless sync

- IP based P2P applications
- Wireless I/O
- Media HotSpot



Kiosk Sync & Nano small Cell



Wireless Display

- HD streams over HDMI or DP
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Wireless Docking

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Distributed peripherals



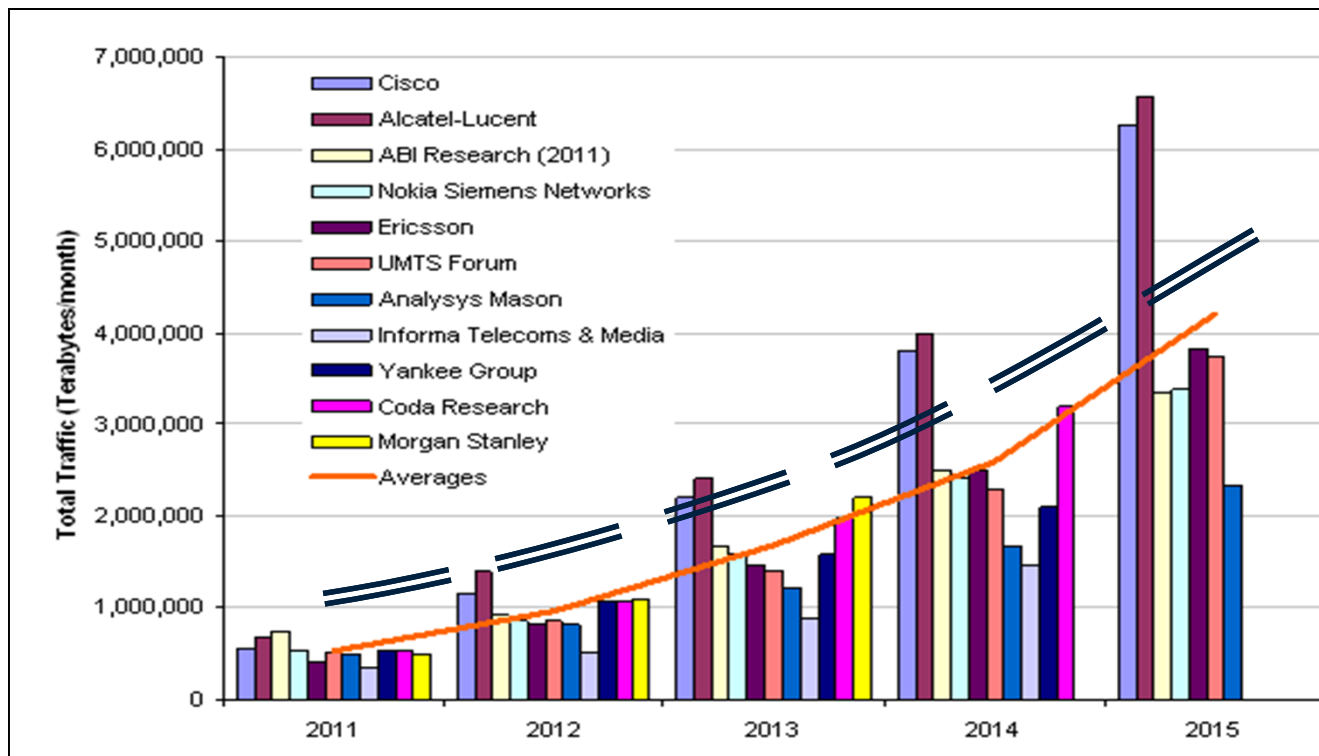
Access

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Exponentially Increasing Capacity

- Multi-company forecast of rapid growth of total traffic¹:



- By 2016: Over 10B connected devices and Global mobile data traffic will reach 10.8 exabytes/month.²

mmWave Advantage

Capacity Increase Technique

Densification (D)

Bandwidth & Throughput (B)

Spectrum Efficiency (S)

mmWave Advantage

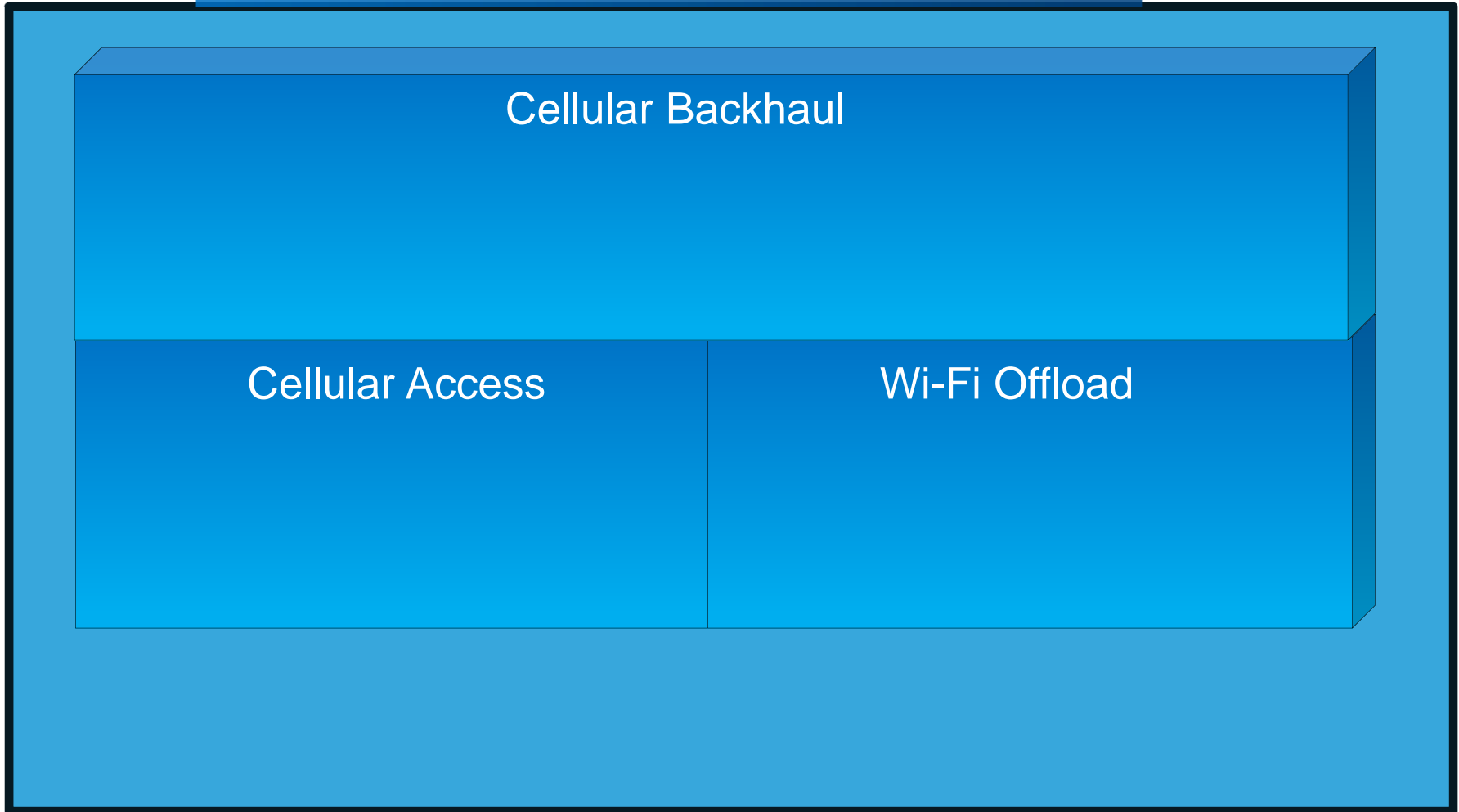
Inherent Shorter Range and Beamsteering Mitigate Interference

mmWave Bands Support Multi-Gbps Rates

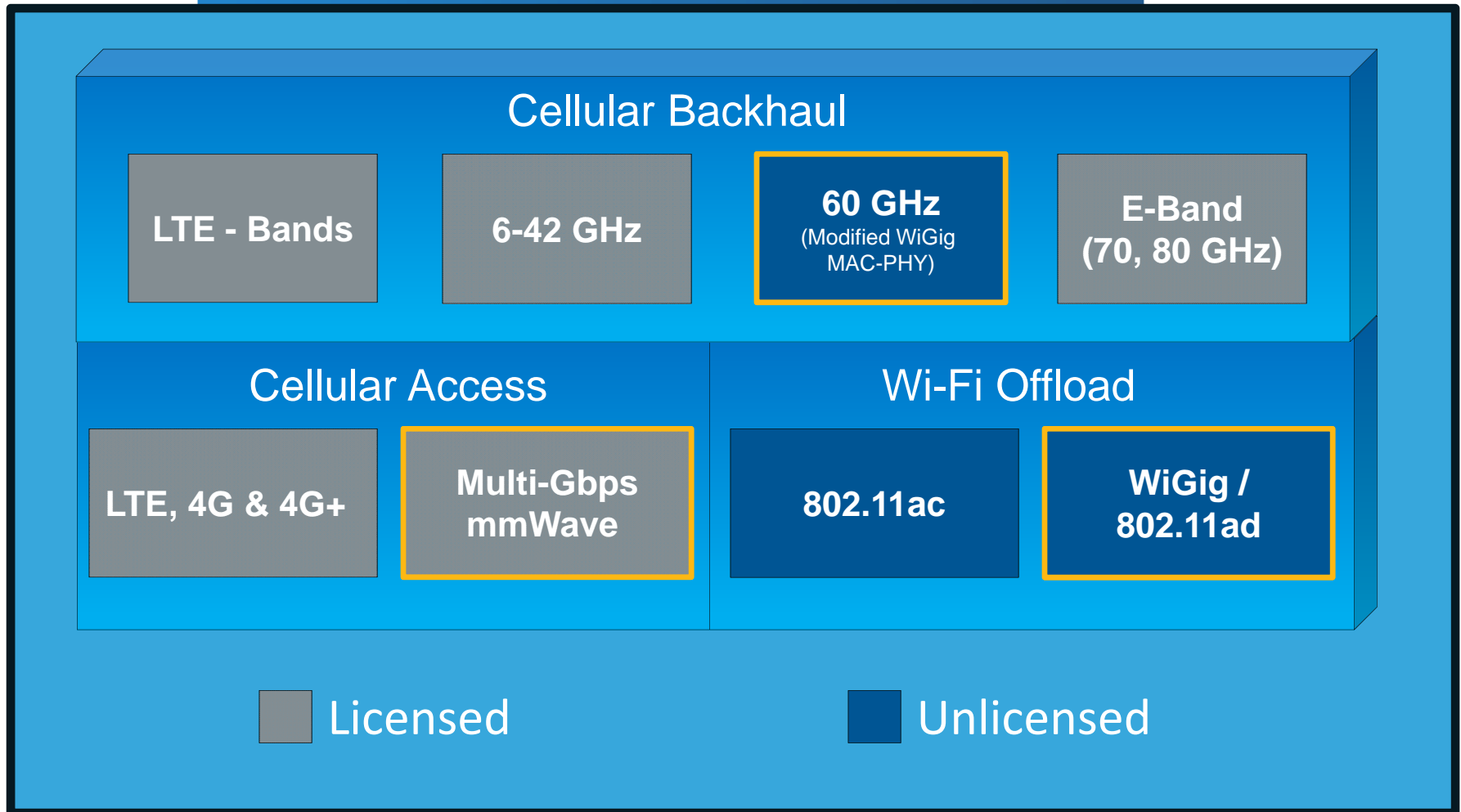
Beamsteering and MU-MIMO Techniques Support PtP and PtMP in Same Frequency Band

$$\text{Capacity Increase} = D \times B \times S > 1000$$

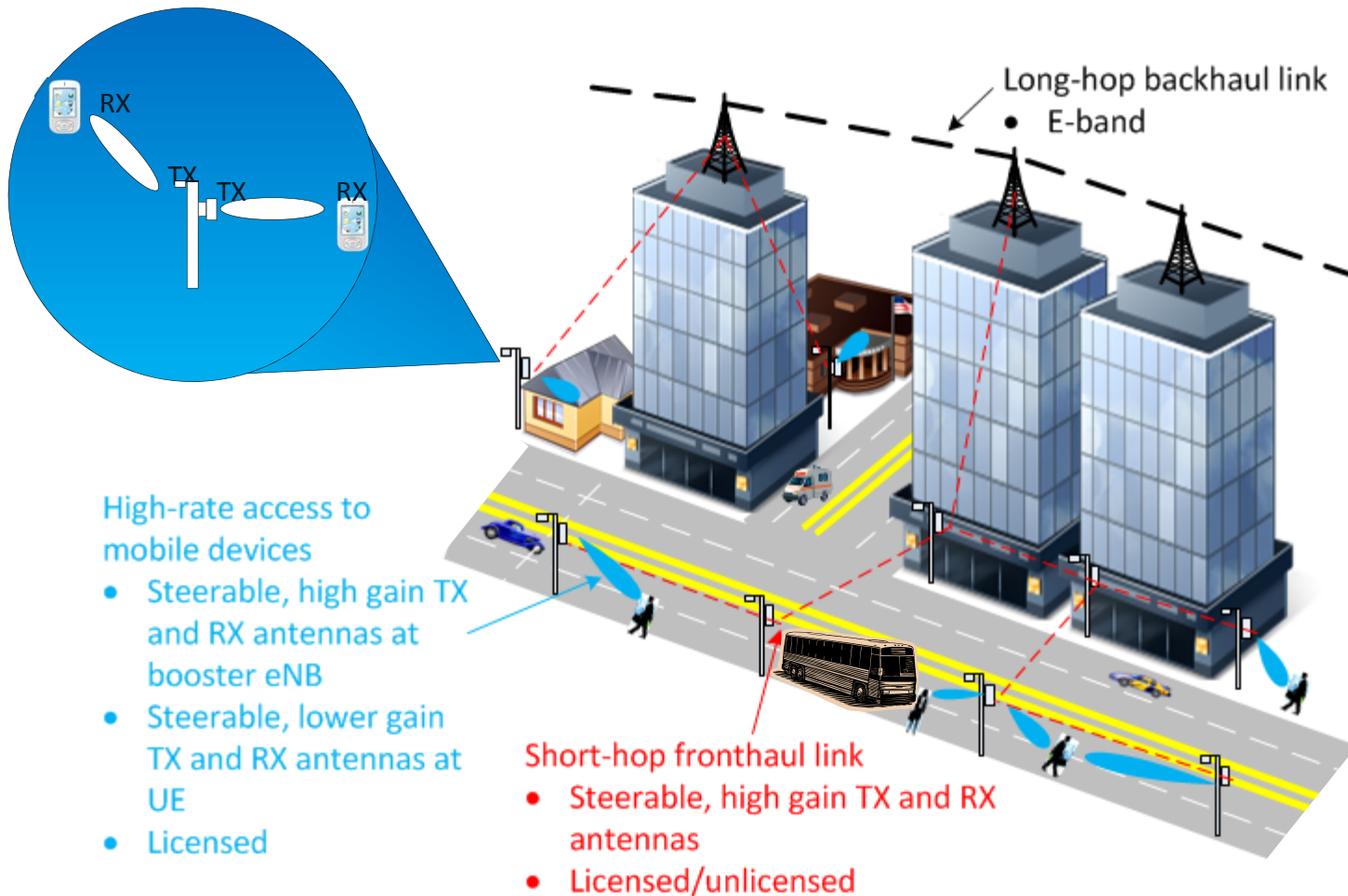
Small Cell Components



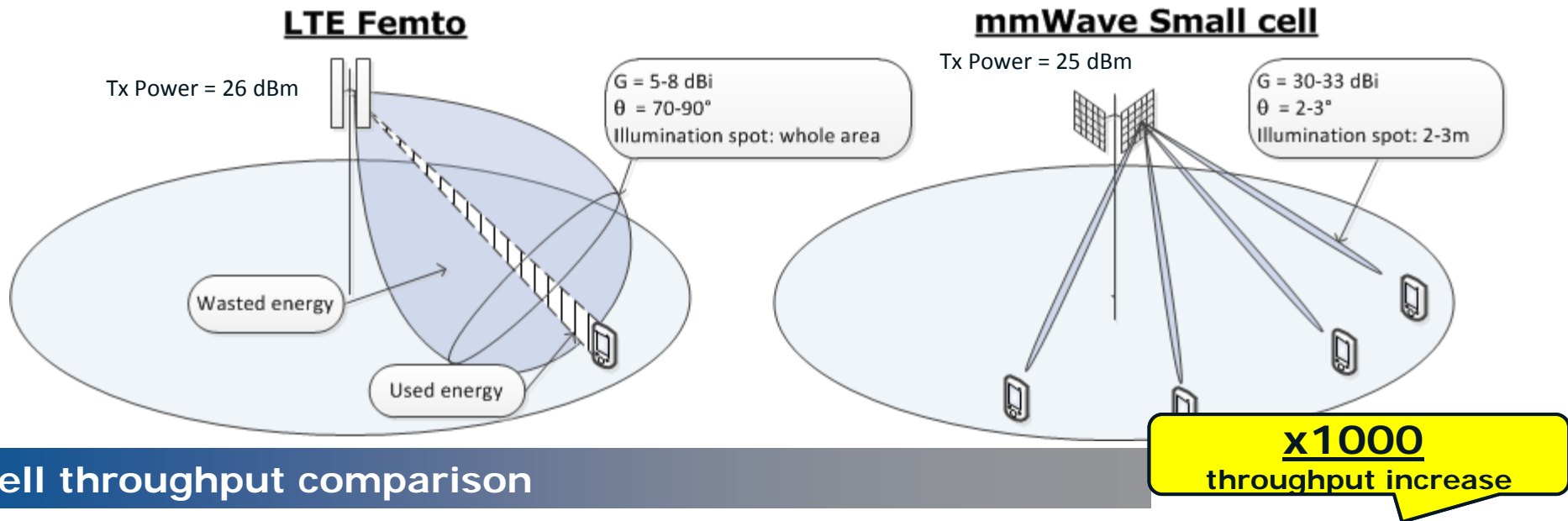
mmWave Capable Small Cells (MCSCs)



The mmWave Enabled HetNet



mmWave Small Cell vs. Modern LTE Femto



Cell throughput comparison

LTE average : 50 Mbps/cell MU

mmWave Small Cell: Up to 4 Gbps SU, 50 Gbps MU

Energy efficiency / beamwidth comparison (green radio)

LTE Femto antenna HPBW: 70-90°

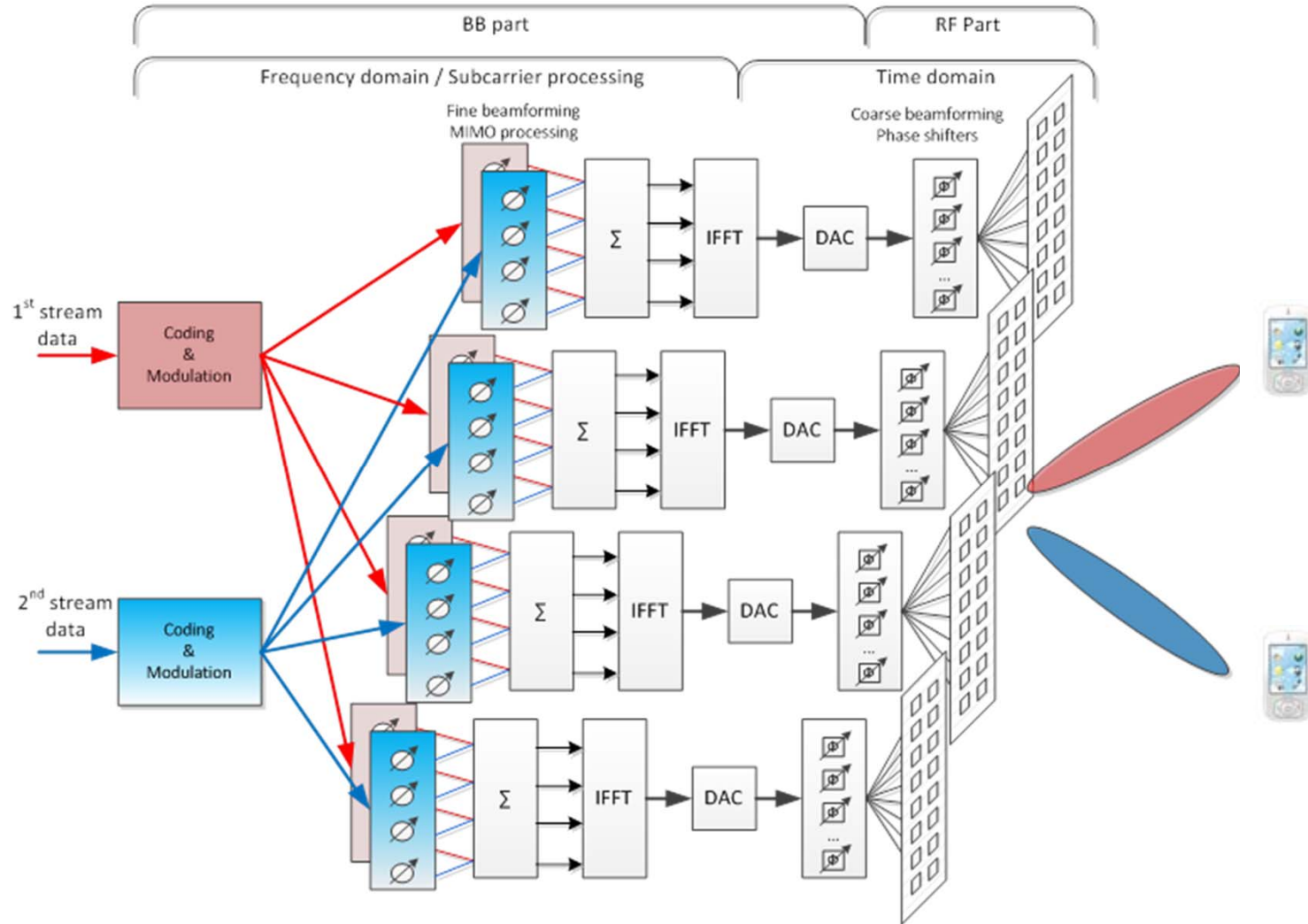
mmWave Small Cell antenna HPBW: 2-3°

New feature: Intelligent beam control

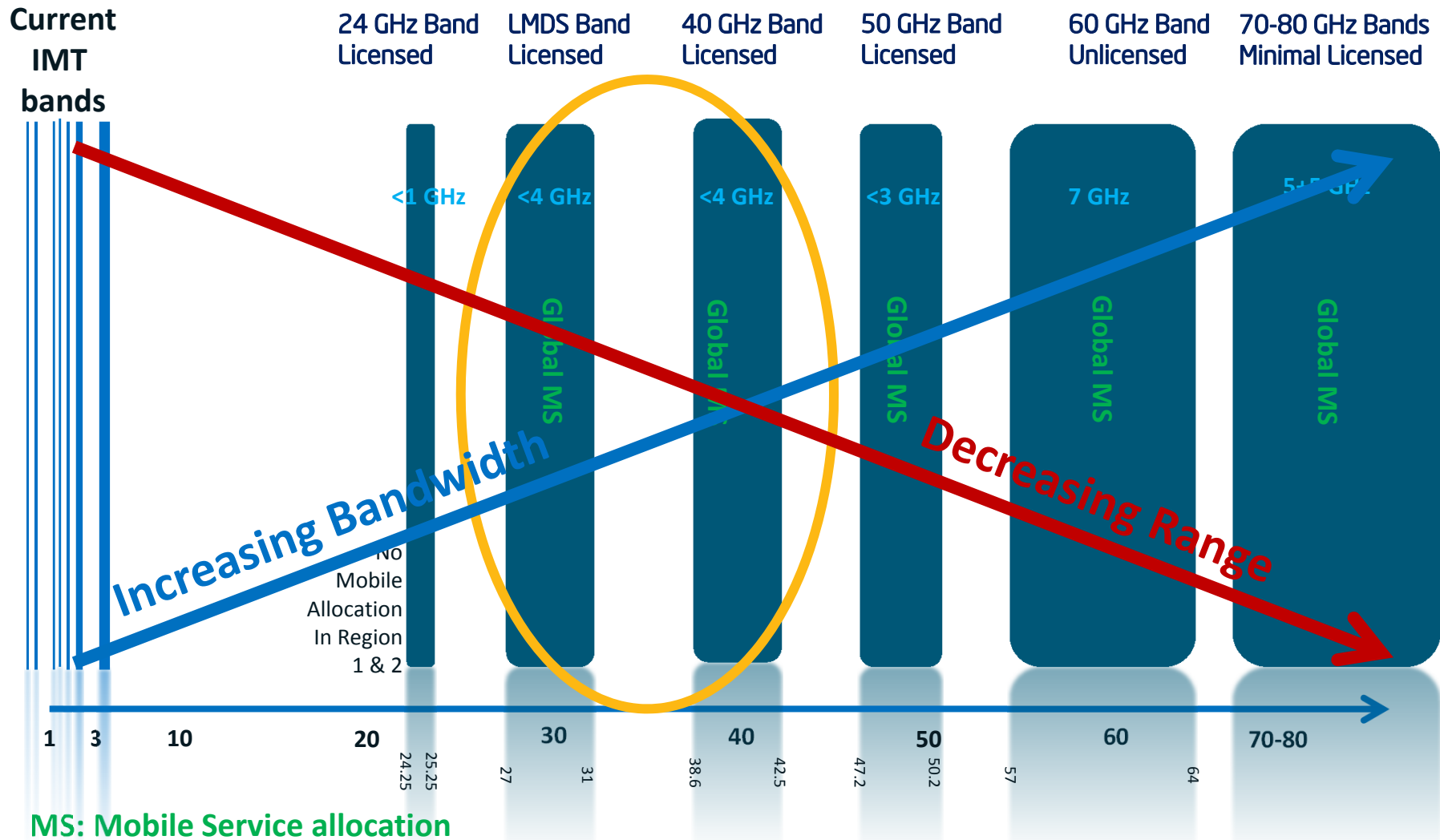
- Per-beam power control to meet QoS and FCC requirements
- Beam steering / Beam tracking and Precise user positioning

x30
Energy efficiency increase

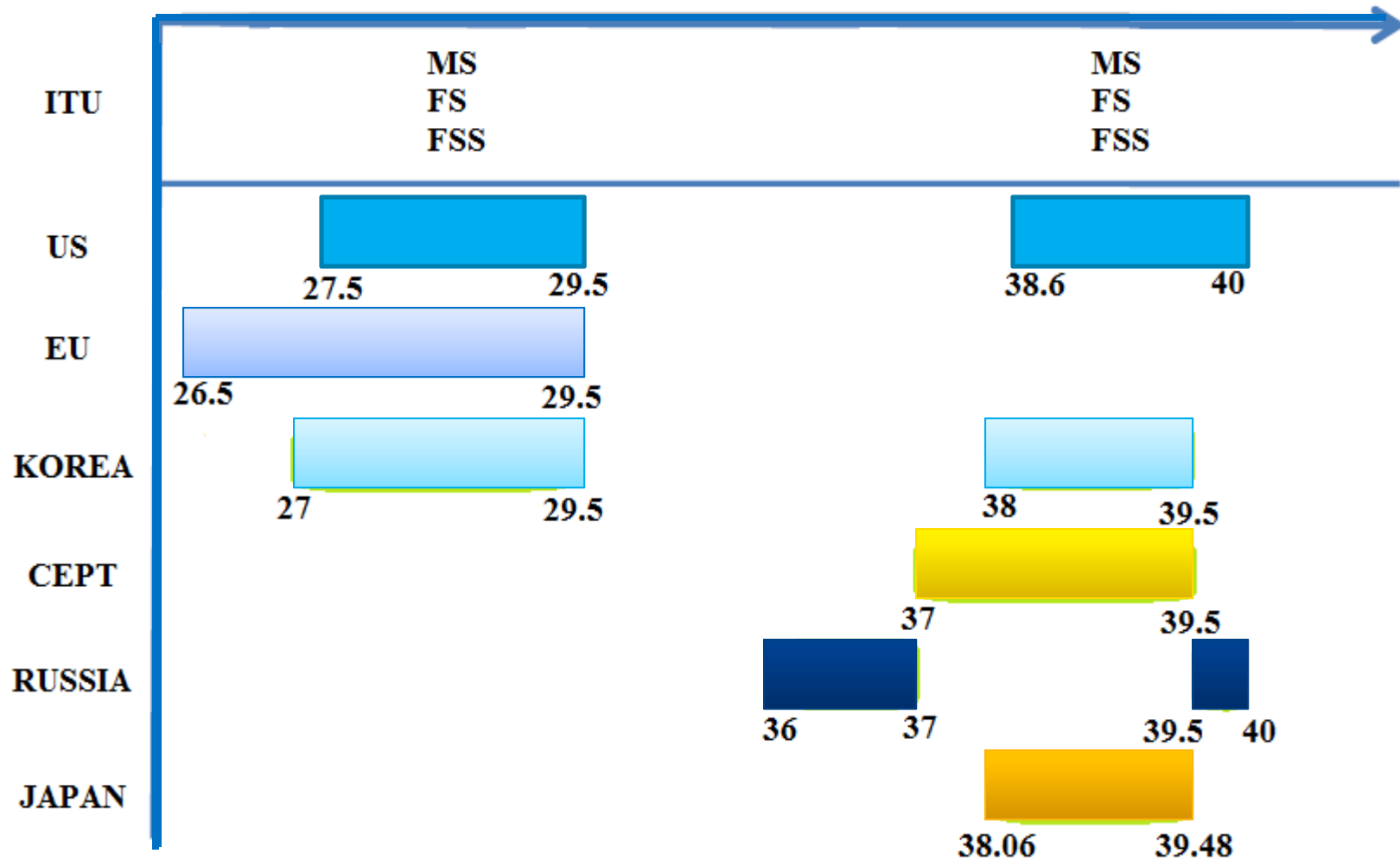
Long Term Goal, MU-MIMO



The Search for Alternate Spectrum

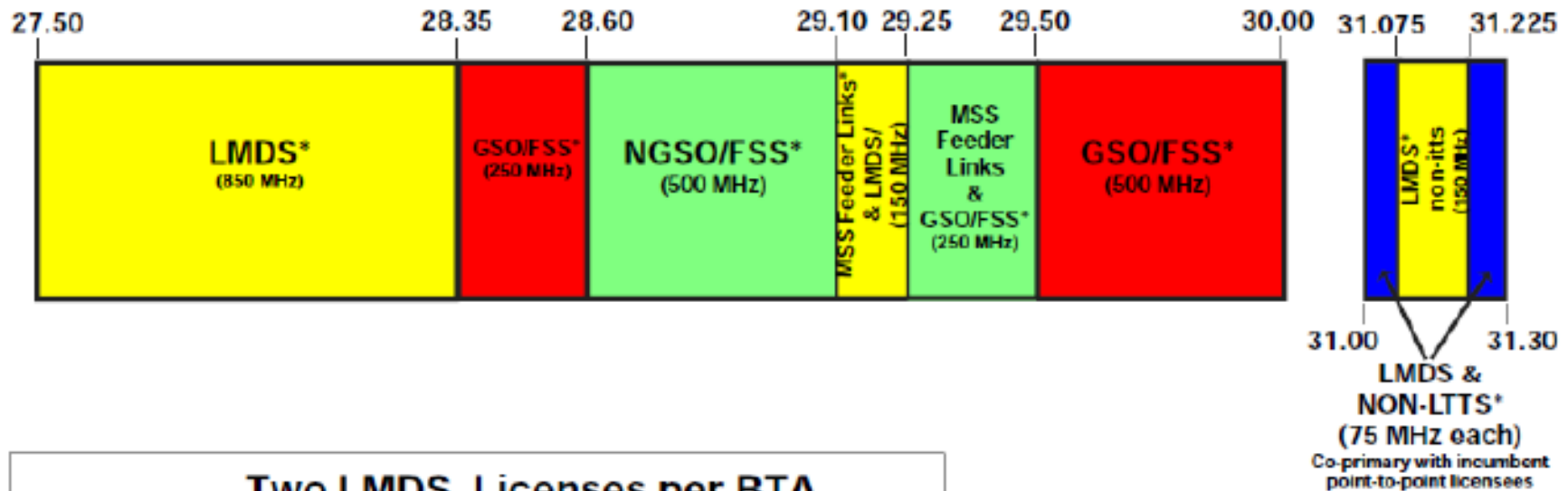


Possible Frequency bands for mmWave Access



LMDS band plan in the US

28 & 31 GHz Band Plan

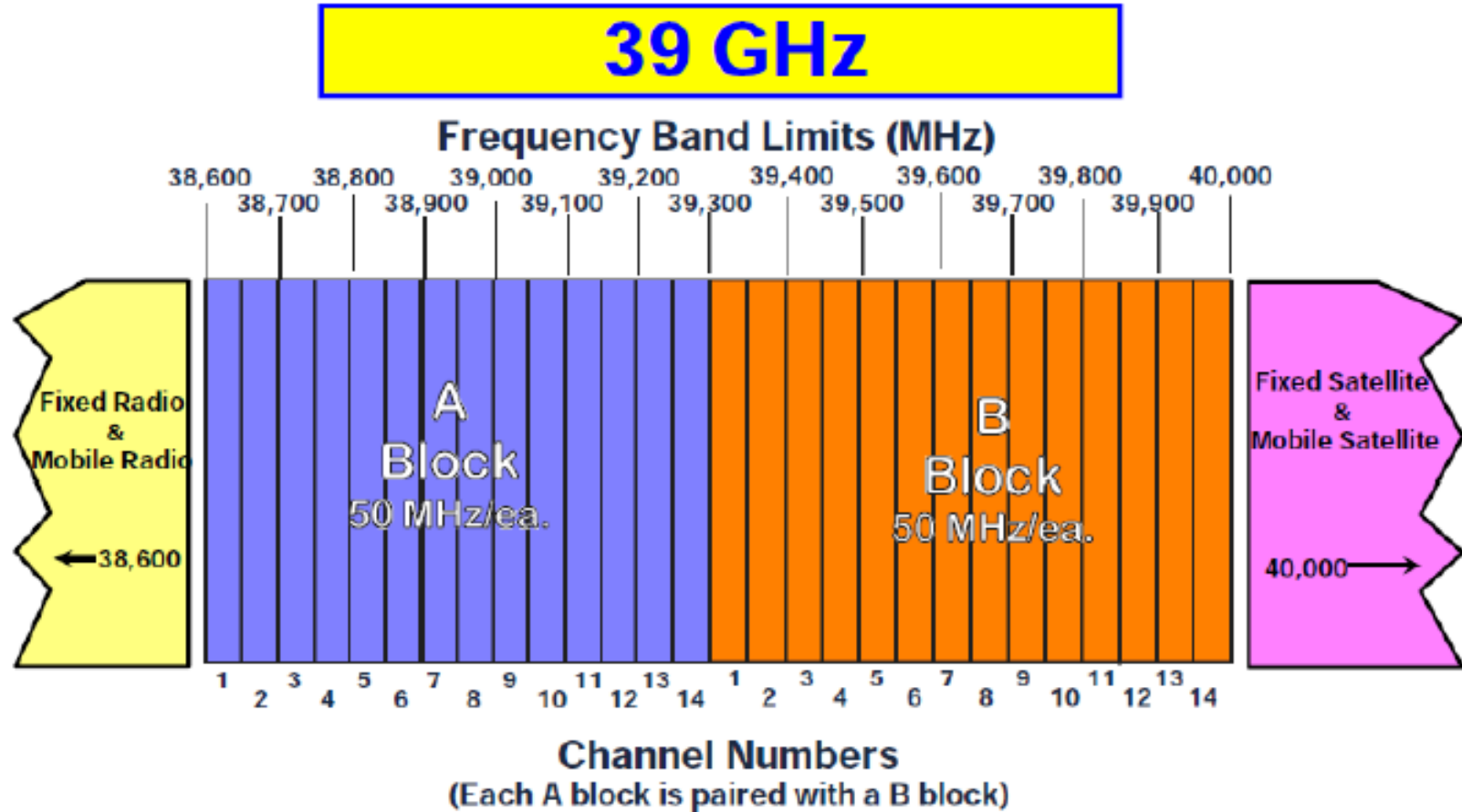


Two LMDS Licenses per BTA

Block A - 1150 MHz:		Block B - 150 MHz:	
27,500-28,350 MHz		31,000-31,075 MHz	
29,100-29,250 MHz		31,225-31,300 MHz	
31,075-31,225 MHz			

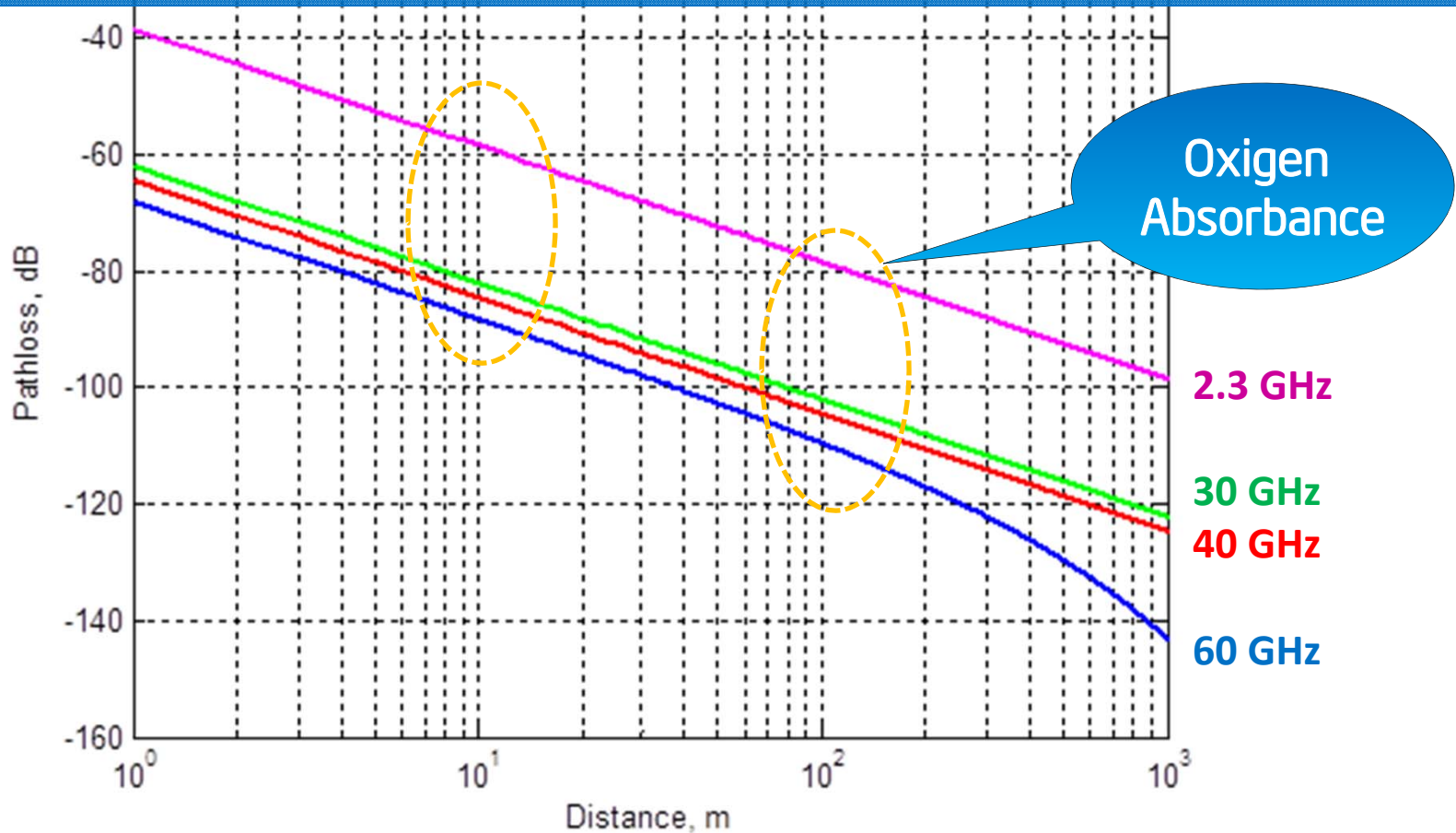
- Legend**
- "" - Primary Service
 - FSS - Fixed Satellite Service
 - GSO - Geostationary Orbit
 - NON-LTTS - Non-Local Television Transmission Service
 - MSS - Mobile Satellite Service
 - NGSO - Non-Geostationary Orbit

39 GHz band plan in the US

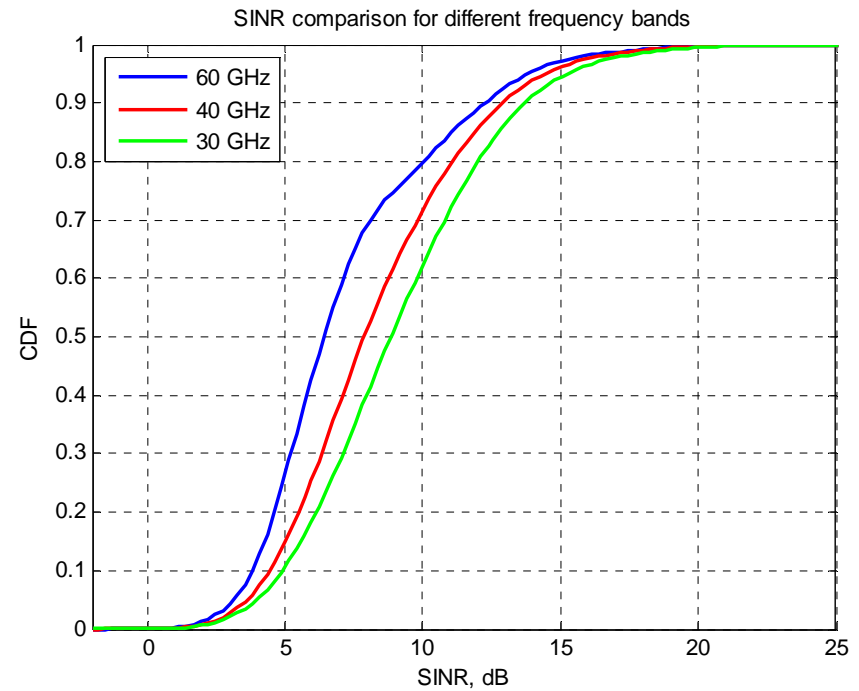
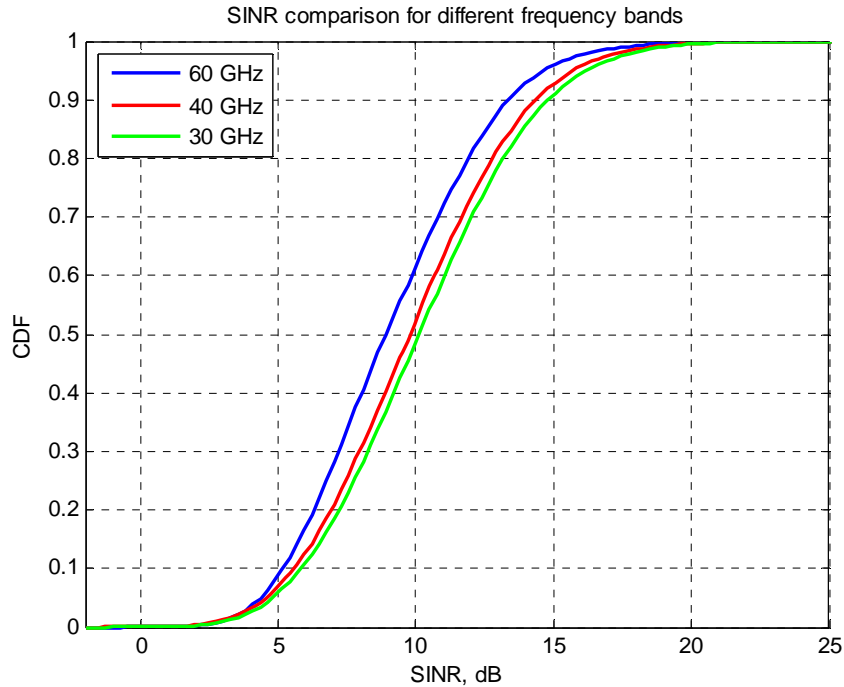


mmWave Path loss Comparisons

Note: Assumption is that we are using the same TX/RX antennas gain for all bands. But it means that antenna size for 30GHz will be two times larger than for 60GHz (aperture size by 4 times bigger!). In the case of hard limitations on antenna size additional **6dB** advantage will be lost for low frequency bands.

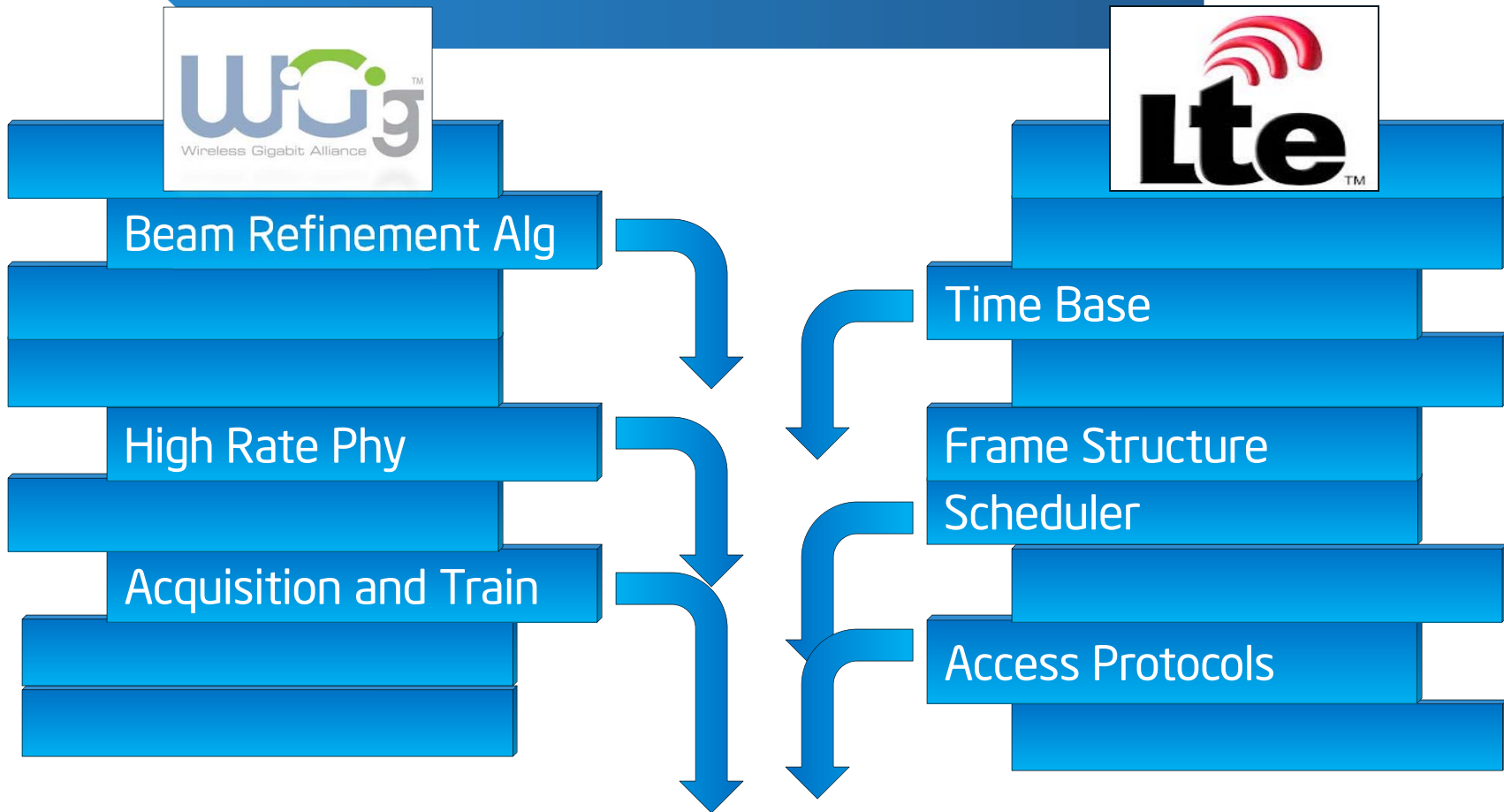


CDF Vs SNR Comparison



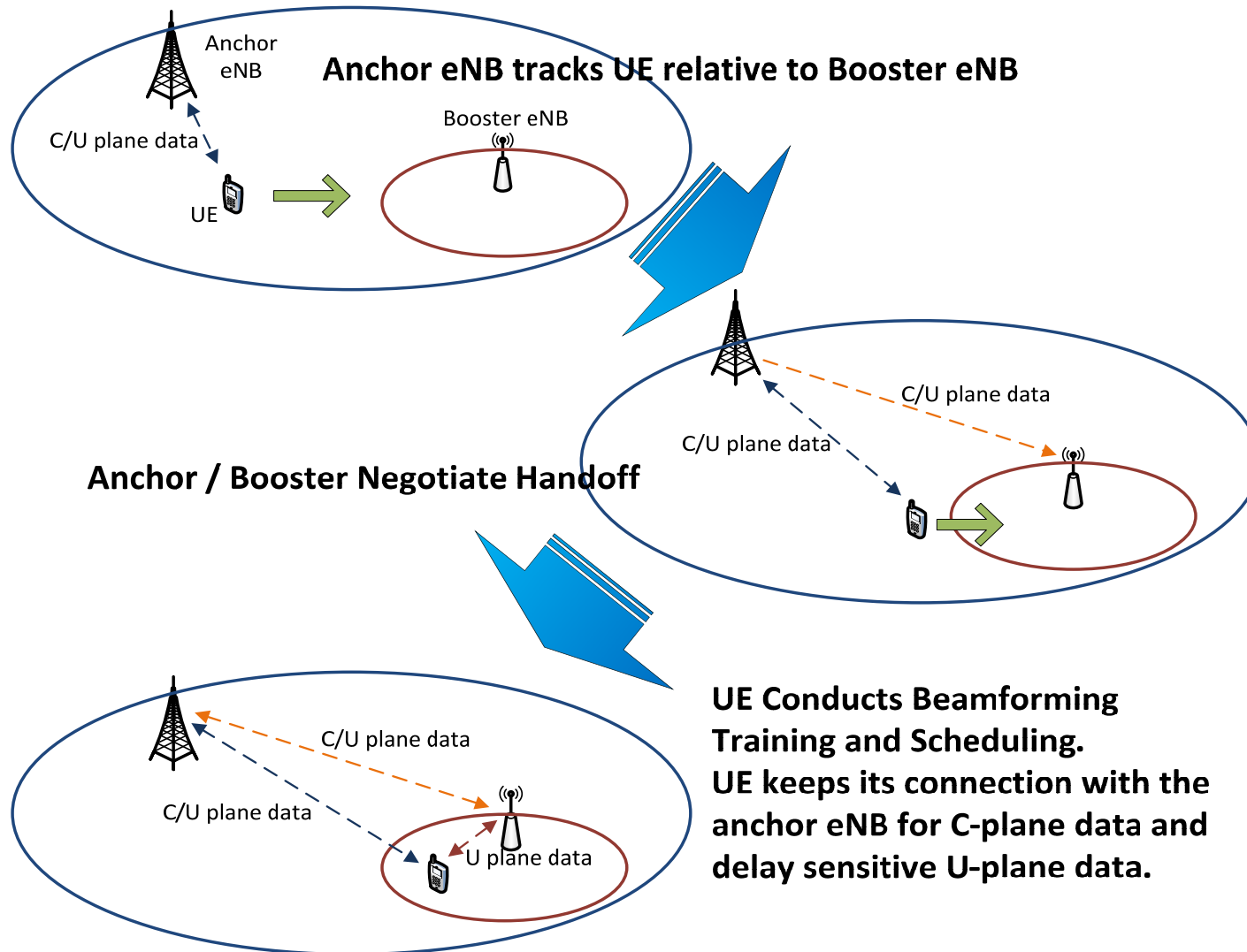
For 100 meters deployment 30 GHz outperform 60GHz on median level by 1.2 dB.
For 200 meters deployment 30 GHz outperform 60GHz on median level by 2.4 dB.

Achieving Compatibility with Legacy Systems



mmWave Enabled 5G

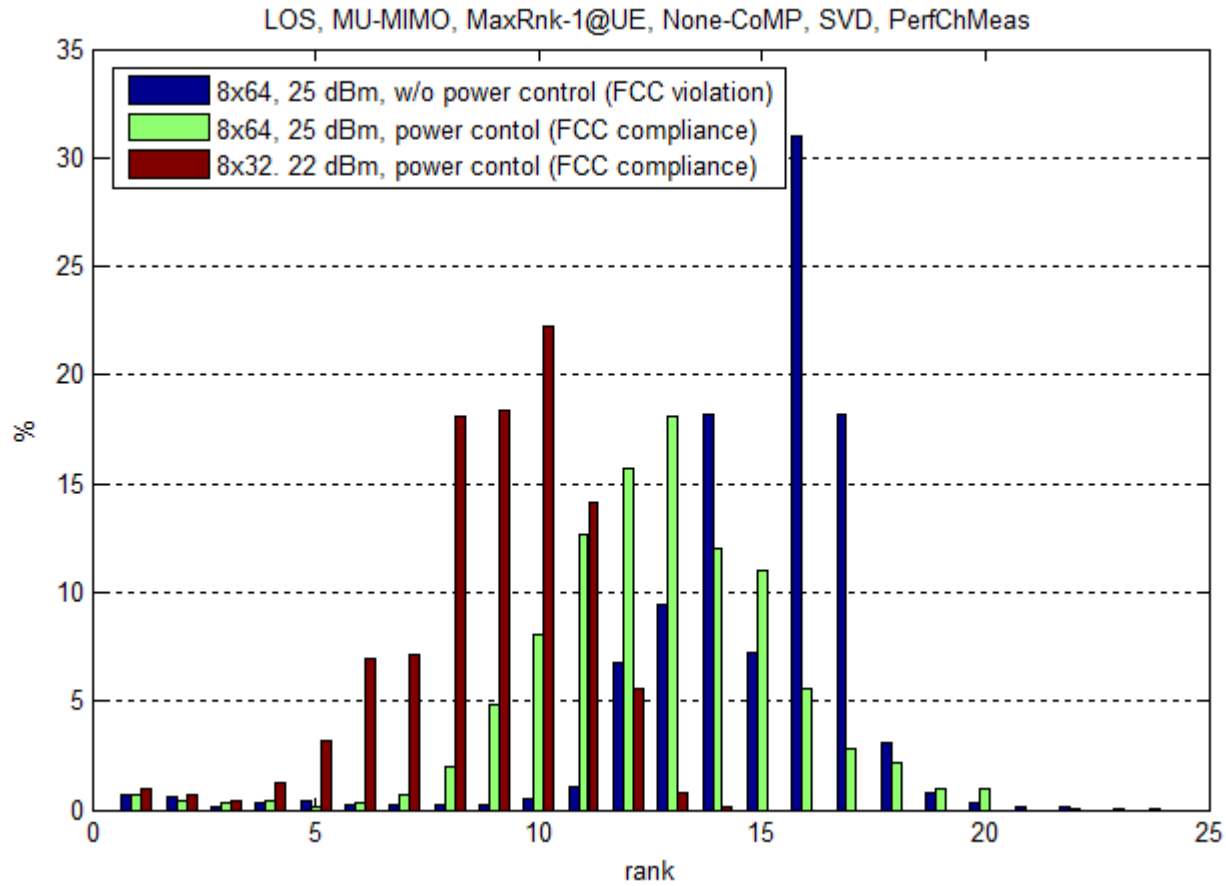
Possible LTE-Assisted Handoff



Early Simulation result

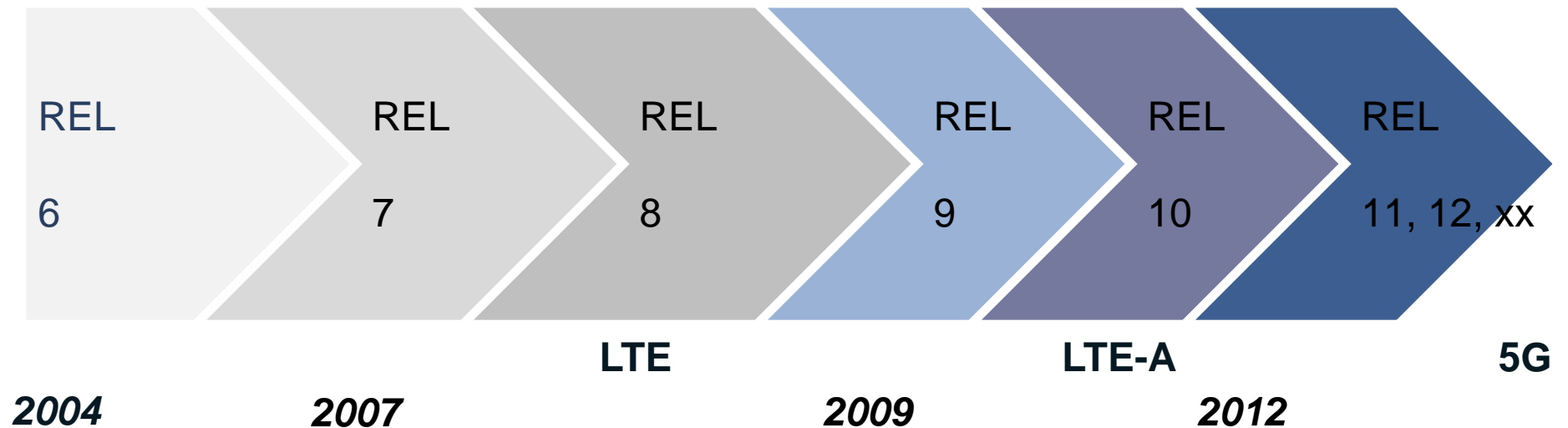
- For SU-MIMO mode mmWave communication system has shown 5.4 Gbps/cell throughput (90 Mbps/UE for 60 UE/cell) for 50 m Small cell size. (No overhead assumed)
- For MU-MIMO mode simulations, under reasonable assumptions, mmWave Small cell demonstrates 59 Gbps/cell throughput (about 1 Gbps/UE for 60 UE/cell) for 50 m Small cell size. (*matching analytical results previously presented*)
- The system without intelligent power transmit power control may violate FCC requirements on signal power density. ITPC scheme prevents this violation without substantial system performance metrics degradation (Sw controlled EIRP/UE)

Simulation results: MU ranks for MU-MIMO modes



Cellular Systems Evolution

A new generation of cellular systems evolves every 5-7 years



Beyond 4G technology research and development begins now!

Summary

- WiGig is a multi Gigabit wireless standards and technology that enhances the usability of WiFi beyond connectivity and networking
- Multi Gigabit connectivity imposes higher capacity to the existing Cellular systems
- To increase capacity, increased small cell density, higher throughput and spectral efficiency systems are required
- mmWave enabled HetNet can significantly increase the system capacity
- WiGig as a proven mmWave technology can be extended to mmWave cellular systems.
- New generations of cellular systems evolve every 5-7 years, mmWave technology is a great candidate for beyond 4G systems